Substance Flow Analysis of Tantalum in Taiwan

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Substance Flow Analysis (SFA) is mainly used to quantify flows and stocks of a particular substance distributed in a finite ecosystem. It can also be used to help decision-makers select the best strategy to implement resource allocation and management. This study focused on tantalum flows in Taiwan in 2013, specifically as tantalum capacitors, powder, and waste products. Tantalum, a rare metal that has a lot of potential, especially in the electronics industry, is not locally produced in Taiwan; so an SFA is vital to monitor supply, demand, and accumulation. Best estimates were done in coordination with Taiwan companies and government agencies, namely: Ministry of Economic Affairs; Ministry of Finance; Customs Department; and Environmental Protection Administration. In 2013, Taiwan imported a total of 340,355 kg of tantalum; 84.5% of this remained in Taiwan either as electronic products or as raw materials, while the rest were exported.

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1. Introduction

Tantalum, a gray-blue high-density hard metal, with melting point of 3017 °C and boiling point of 5458 °C, is classified as a scarce resource. According to US Geological Survey, tantalum in the Earth’s crust has limited natural reserves of 400,000 tons, with even more limited recoverable reserves of more than 43,000 tons. Varied industry characteristics of different countries cause varying definitions of scarce resources, but Table 1 summarizes these definitions. Scarce resources are also vulnerable to different supply policies and political considerations that could result to price volatility. It is important to understand that there are no official prices for tantalum commodities, as this metal is not traded on any metal exchange. The price is determined solely by negotiations between buyer and seller.

The major use of tantalum is for electronic components such as capacitors and high power resistors, because, as metal powder, it has a tendency to form a protective oxide surface layer. In 2012, tantalum, primarily as powder and capacitors, had global production of about 765 tons. Mozambique, Brazil, Congo, Rwanda, and Nigeria are the main producers accounting for more than 80% of the world production. Taiwan, despite relying solely on imports, is also a major player in the use of tantalum, being one of the leading countries to manufacture semiconductor wafers and optoelectronic components. It has also developed the related production and recovery technology of high purity tantalum powder. To understand the flow of the pulsating tantalum scarce resources and explore the possibility of efficient recovery of precious metals, this research work concentrated on the tantalum substance flow analysis (SFA). SFA is a systematic assessment of the flows and stocks of materials within a system defined in space and time. One of its major applications is in resource management, specifically on analysis, planning, allocation, exploitation, and upgrading of resources. This research aims to assess relevant flows and stocks of tantalum quantitatively, checking mass balance, sensitivities, and uncertainties. The results could be used by Taiwan government as basis for managing tantalum resource and wastes, monitoring accumulation or depletion of stocks and future environmental loadings. The results could also be used to design environmentally-benignic goods, processes, and systems.

2. Methodology and Data Source

SFA assists decision-makers to investigate and understand storage and flow of materials in a specified system. It asks whether the flow of materials is sustainable in terms of the environmental burden it creates. It accounts for all materials and energy used in production and consumption, including the hidden flows or ecological rucksack of materials that were extracted in the production cycle but which never entered into the final products. This system includes: input, output, and stock; basic analysis of the SFA program; and steps described in Fig. 1 below:

Table 1 Definition of scarce resource.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Explanation</th>
<th>Scarc Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore resource reserves</td>
<td>Endowments, distribution and production be concentrated in a few countries</td>
<td>Less content in the earth’s crust and difficult to mine</td>
</tr>
<tr>
<td>Demand</td>
<td>Add a small amount in the manufacturing process, features and performance of products dramatically increase</td>
<td>Exploration and production in a few countries</td>
</tr>
<tr>
<td>International Factors</td>
<td>Affected by countries supply policy and political considerations.</td>
<td>Suppliers Resource protectionism</td>
</tr>
<tr>
<td>Technology</td>
<td>Extraction, separation, difficult processing that only a few countries have these technology</td>
<td>Difficulties of refining and processing technical</td>
</tr>
</tbody>
</table>

Source of the materials: T.C Chang

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2.1 Identification of System Boundaries

Tantalum SFA in Taiwan is limited to year 2013.

2.2 Identification of components of the system

Components include import, export, and accumulation. These components can be any of the tantalum-containing products classified as powder, waste, or capacitor based on the tariff number classifications, as shown in Table 2.

2.3 Identification of Constraints

Legal constraints on the responsibilities of enterprises, manufacturers, and importers as regards recycling, clearance, and disposal of products, help to reduce the uncertainty on estimation and calculation of material flow distribution and improve the accuracy of statistical scale.

At present, there is still no relevant tantalum SFA database available in Taiwan and available information was insufficient to specify uncertainty for some stock and flow data. However, based on the authors’ judgment on data sensitivity, highly confidential data include official data from different government agencies in Taiwan, surveyed data from different companies, and estimated or validated data mainly based on official data and surveyed data. Lower confidential data include the market share of different companies that could be prejudiced by company image, among others. However, all data in the results have been validated by careful mass balance.

2.4 Data acquisition and inventory

Aside from literature search and market research, the two major sources of information for this study are: (1) government agencies; and (2) High-Tech companies in Taiwan.

Government agencies that provided data on import and export of tantalum in Taiwan include Ministry of Economic Affairs; Ministry of Finance; Customs Department; and Environmental Protection Administration.

High-tech companies in Taiwan are listed in Table 3. These companies provided enough information for the estimation of the total tantalum used for the manufacture of capacitors, using eqs. (1) and (2).

\[ T_{acap} = \sum T_{apdt} \]  

\[ T_{apdt} = \frac{SA}{MS}(0.15) \]  

where: \( T_{acap} \) is the total amount of tantalum in capacitors in Taiwan for the year 2013; \( T_{apdt} \) is the amount of tantalum in a specific product; \( S_A \) is the surveyed amount of each type of product, based on interview with different companies; \( M_S \) is the market share of that specific product; and 0.15 is the 15% tantalum content of capacitors as recommended by the companies to be used for the estimation, as shown in Table 4.

From the total amount of imported tantalum, the amount of non-capacitor products (powder) can be computed using eq. (3).

\[ T_{apowder} = T_{Timp} - (T_{acap} + T_{aw}) \]  

where \( T_{Timp} \) is the total amount of imported tantalum; \( T_{acap} \) is the total amount of tantalum in capacitors; and \( T_{aw} \) is total amount of tantalum in waste or scrap.

Tantalum powder is high-purity tantalum powder that is free of impurities. In this study, tantalum powder or simply...
powder is used to refer to non-capacitor products, or products other than capacitors that are containing tantalum. The amount of waste can be computed using eq. (4).

\[ w_T = w_{\text{imp}} + w_{\text{cap}} + w_{\text{powder}} \]  

(4)

where \( w_T \) is the total amount of tantalum in waste that will be exported; \( w_{\text{imp}} \) is the amount of imported tantalum in waste or scrap; \( w_{\text{cap}} \) is the amount of tantalum in the waste in the production of capacitors; and \( w_{\text{powder}} \) is the amount of tantalum in the waste in the production of non-capacitor products.

The amount of tantalum accumulation in Taiwan for 2013 can then be computed using eq. (5).

\[ T_{\text{acc}} = T_{\text{Timp}} - T_{\text{Tex}} \]  

(5)

where \( T_{\text{acc}} \) is tantalum accumulation in Taiwan; \( T_{\text{Timp}} \) is the total amount of imported tantalum; and \( T_{\text{Tex}} \) is the total amount of exported tantalum.

3. Results and Discussion

According to the ROC Ministry of Finance Directorate General of Customs, in 2013, Taiwan imported a total of 340,355 kg of tantalum, as shown in Table 5. This table also shows the major categories of tantalum products: capacitors and powder. Tantalum powder represents all tantalum in Tai-
Tantalum powder is also referred to as non-capacitors. This simplification was done for better tracking of tantalum flow in coordination with leading companies and government agencies in Taiwan. Tantalum capacitors accounted for 200,357 kg of tantalum, which is about 59% of total tantalum import. The other 41% was attributed to tantalum powder (139,911 kg). Out of the total imported amount, 87 kg was waste and scrap; and this is less than 1% of the total imported amount of tantalum.

In 2013, the domestically available tantalum capacitors were all imported, since there were no local manufacturers. Using eqs. (1) and (2), the estimated total amount of tantalum capacitors (200,357 kg) was computed. Table 6 shows the breakdown of this amount into specific products. eq. (2) factored in three (3) important items: SA; MS; and 0.15. SA is the surveyed amount of each type of product shown in Table 6. These amounts were the results of meticulous survey from leading high-tech companies in different industries in Taiwan (Table 3) that also disclosed their estimated market share (MS) for different products. Due to confidentiality agreement, these specific values cannot be shown in this paper. These two values, SA and MS were used to compute for the estimated total market of capacitors for each product in the different industries. The last item to be factored in was the 15% tantalum content of capacitors. This information was given by Holy Stone Enterprise Co., Ltd that claims that capacitors contain an average of 15% tantalum by weight. Equation (1) was then used to get the total amount of tantalum in capacitors in Taiwan for the year 2013. Table 6 gives the summary of the estimated amount of tantalum per product using data from industry survey, factoring in the market share of the particular company surveyed to estimate the total production in Taiwan. From Table 6, it can be seen that tantalum capacitors is mostly used for switch-type power supply.

### Table 6: Estimated amount of tantalum per product based on industry survey.

<table>
<thead>
<tr>
<th>Ta-containing electronic products</th>
<th>Manufacturers</th>
<th>Estimated amount of Tantalum (kg/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch-type power supply</td>
<td>Finesse Technology Co., Ltd. Cincon Electronics Co., Ltd.</td>
<td>72,857</td>
</tr>
<tr>
<td>Charger</td>
<td>Cincon Electronics Co., Ltd</td>
<td>21,429</td>
</tr>
<tr>
<td>Rear Projection Machine</td>
<td>Lumens Integration, Inc.</td>
<td>19,286</td>
</tr>
<tr>
<td>Motherboard</td>
<td>BCM Computers Co., Ltd</td>
<td>17,143</td>
</tr>
<tr>
<td>Digital Projector</td>
<td>Lumens Integration, Inc.</td>
<td>9,643</td>
</tr>
<tr>
<td>Other electronic products</td>
<td>Might Electronics Co., Ltd.</td>
<td>60,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>200,357</strong></td>
</tr>
</tbody>
</table>

### Table 7: Taiwan 2013 exports of products containing tantalum.

<table>
<thead>
<tr>
<th>Product</th>
<th>kg</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tantalum capacitors</td>
<td>21,200</td>
<td>40.2</td>
</tr>
<tr>
<td>Tantalum powder</td>
<td>28,000</td>
<td>53.1</td>
</tr>
<tr>
<td>Tantalum waste and scrap</td>
<td>3,490</td>
<td>6.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>52,690</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

**Fig. 2** SFA of tantalum in Taiwan in 2013.
Then, using eq. (3), the amount of tantalum powder was computed. This was done by subtracting the accounted for amount of tantalum in capacitors from the total amount of imported tantalum.

Still in coordination with government agencies in Taiwan, data on exportation of tantalum was summarized in Table 7 that shows the exported amount of tantalum as capacitors, powder, or waste. The total exported amount of tantalum was 52,690 kg. For uniformity, the categories used in the summary of importation of tantalum were used for the exportation data. Capacitors, which amounted to 21,200 kg of tantalum, accounted for 40.2% of exported tantalum. Non-capacitors (powder) had 28,000 kg and accounted for 53.1% of exported tantalum. The remaining 6.6% of exported tantalum, which is equivalent to 3,490 kg, was wastes or scrap.

Using eq. (4), the total amount of tantalum in the waste or scrap was calculated. This is also by assuming, as recommended in the industry survey, that the waste production is 1% of the raw material. From this, the total accumulation of tantalum in Taiwan was computed using eq. (5). Figure 2 shows the complete SFA of tantalum in Taiwan for the year 2013. The total accumulated amount of tantalum in Taiwan for the year 2013 was 287,665 kg.

4. Conclusions

This study investigated the amounts and directions of tantalum flow within Taiwan in 2013.  
(1) Based on extensive survey and coordination with leading Taiwan companies and government agencies, the total import of tantalum in 2013, was 340,355 kg, while the total export was 52,690 kg.
(2) From the total import, 287,665 kg of tantalum, or 84.5% remained in Taiwan economy in 2013. The major use of tantalum was in capacitor, accounting for 61.6%.
(3) Accounting for waste generation, it was estimated at 3,490 kg of tantalum.

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REFERENCES